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Analysis of the Power Consumption for Wireless Sensor Network Node Based on Zigbee

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Abstract

Study the prominent characteristics of ZigBee technology on wireless sensor networks, especially on the power consumption of the nodes. In order to reduce the power consumption of wireless sensor network node, this paper simulate the relation between the power consumption and the signal to noise ratio for the communications modulation, the relation between the power consumption and the transmission delay for the sleep mechanism, and the relation between the power consumption and the network throughput for MAC, by hardware structure and MAC protocols of the physical layer of the wireless sensor network node. And analyse the power consumption of the wireless sensor network node further. The modulation of PSK consumes the least power in all of the modulations of the wireless sensor network node obviously; the power consumption of EEMAC is the lowest in the MAC. The results show that the algorithm of EEMAC and the modulation of PSK are very compatible with the cooperations of many nodes. These results are very helpful to the structure optimization of the wireless sensor network node of ZigBee and the reducing of the power consumption of transfer data.

Keywords: Wireless Sensor; Sensor Node; ZigBee; PSK; EEMAC

1. Introduction

ZigBee[1,2] is a new wireless network technology for its short range, low speed, low power consumption and low cost. It is a technology solution between the wireless technology and Bluetooth. It uses a direct sequence spread spectrum (DSSS) technology of working frequency with 868MHz,

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915MHz and 2.4GHz. The frequency of DSSS does't need to apply a licences. It is adapted to the communications data of small volume and the occasion of lower data transfer efficiency. The security and reliability of data have a set of requirements, and its cost and power consumption are very low. Therefore, ZigBee has broad application prospects in industrial control, automation of industrial wireless positioning, home networking, automotive, medical equipment control and other fields in the next few years[3-9]. ZigBee chips will be the main field of application for home automation and industrial control in the future. Because of the small of technical research and the insufficiency of related data，the ZigBee technology has not been universal in our country. This paper simulate the relation between the power consumption and signal to noise ratio for the communications modulation, the relation between the power consumption and transmission delay for the sleep mechanisms and the relation between power consumption and throughput for the MAC for the sensors network node . The results will be great reference value for understanding the power consumption of ZigBee wireless sensor network node.

2. Analyse of the power consumption of ZigBee nodes

2.1. The energy saving strategy of the communication module

The energy saving strategy of the communication module mainly consists of the communication modulation, increasing the sleeping time and the wireless communication method of multihopping short-range.

(1)The communication modulation

There are three types of modulations for the communication modulation: the amplitude shift keying (ASK), the frequency shift keying (FSK) and the phase shift keying(PSK). The ASK is a digital modulation, and its amplitude of carrier waves changes with the Digital Baseband Signal. The FSK is a modulation technique, and its input signal is showed as the phase of its carrier waves. The PSK is a phase modulation technique, and its carrier waves phase could be alternated freely between two numerical values for its two levels of the Digital Baseband Signal.

This paper simulates the signal-noise ratio and the power consumption of the ASK, the FSK and the PSK with Matlab7.1. It researches the power relations of the three, and result is shown as Fig.1.

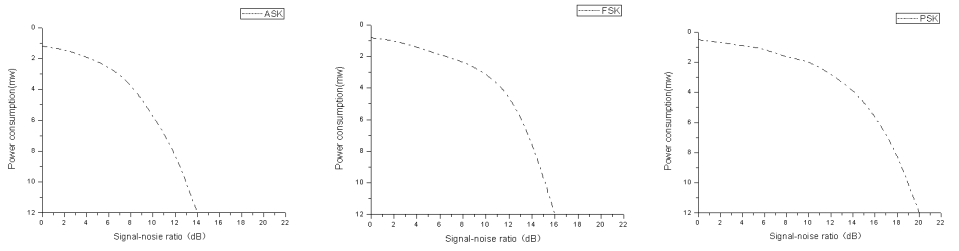

Fig.1. (a) the relation between the power consumption and the signal-noise ratio of ASK; (b) the relation between the power consumption and the signal-noise ratio of FSK; (c) the relation between the power consumption and the signal-noise ratio of PSK

The result shows that the power consumption of PSK is 1.8mw, the power consumption of FSK is 2.2mw and the power consumption of ASK is 3.6mw in the same signal-noise ratio of 8dB. The power consumption of nodes from low to high are the PSK, FSK and ASK in the same signal-noise ratio. The power consumption of PSK is lower than the power consumption of FSK, and the reason is the PSK is good at against the noise, it has a higher transfer rate. The power consumption of FSK is

lower than the power consumption of ASK, and the reason is that the FSK is good at against the noise and decay than the ASK, and it was used earlier. So the power consumption of PSK is the lowest in all of the above in design and realized of the wireless sensor network nodes. And it is very compatible with the cooperations of many nodes.

(2) Increasing the sleeping time

The wireless communication module consumes most of the power in the design and implementation of wireless sensor network nodes. The wireless module has four states in the process of running the network: sending, receiving, free time and dormancy. The four state's energy consumption are difference.

The expression of average power consumption of each node receiving a signal is:

$$P_{ZigBee} = P_S + \frac{p_{RX}(T_W + T_I + T_C)}{T_S + T_I} + \frac{P_{TX}T_C + P_{RX}(T_D + 2T_T)}{L} \quad (1)$$

Where: P_S is the power consumption of the node in a sleep state, P_{RX} is the average power consumption in a accepting state, P_{TX} is the average power consumption in a launching state, T_S is the sleeping time in a sleep state, T_I is the time in the free state, T_W is the time of state of transceiver from sleep to free, T_T is the shifting time between sending state and receiving state, L is the time of each node received a packet, T_D is the transmission time of the packet and T_C is the controlling packet, the shifting time from free state to launching and accepting state could be ignored.

The expression of the transmission delay of ZigBee network is:

$$D_{ZigBee} = \frac{1}{2}T_S + \frac{1}{2}T_I + 2T_C + 2T_T + T_D \quad (2)$$

Where： T_S is the sleeping time in a sleep state, T_I is the time in the free state, T_C is the controlling packet, T_T is the shifting time between sending state and receiving state, T_D is the transmission time of the packet.

This paper simulates the relation between the power consumption and the transmission delay of ZigBee network with Matlab7.1, the result is shown in Fig.2.

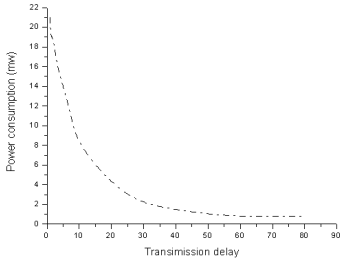

Fig.2. the relation between the power consumption and transmission delay

The result shows that the shorter the T_s, the less transmission time delay, the higher the quality, the greater the power consumption. The reason is the communication could be overlap when two frames information send at the same time. Then the signal of receiving is difficultly to identify and the information need to resend. The resending leads to the waste of the power caused by conflict. It should find the balance between the power consumption and transmission time delay, it can satisfy the quality of channel and minimize the power consumption as much as possible. And it is very compatible with the cooperation of many nodes.

(3) Wireless communication method of multihopping short-range

The wireless communication method of multihopping short-range could reduce the power consumption of the communication module. The relation between communications energy consumption and communications range is $E = Kd^n$, where 2<n<4. So the density of sensor nodes would be disposed properly and the single-hop communication range would be reduced in the context of communication rate satisfied. The radius communications of sensor node should be within 100m, on the basis of theoretical analysis and a lot of experimental data.

2.2. Research the power consumption of the nodes on the MAC layer

The throughput is a metric mode. It is used to calculate the message passing the channels. The adaptive backoff mechanism of adaptive backoff exponent (ABE) could make the channel-jamming of the network expand, and it could relax the network channel-jamming to a certain extent. EEMAC is a modified algorithm of MAC. The relation between the power consumption and the network throughput of ABE, EEMAC and MAC802.15.4 would be simulated by Matlab7.1. The result is shown as Fig.3.

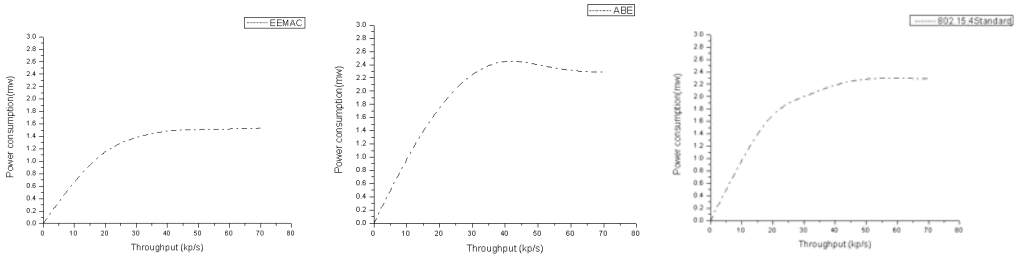

Fig.3. (a) the relation between the power consumption and the network throughput of EEMAC; (b) the relation between the power consumption and the network throughput of ABE ; (c) the relation between the power consumption and the network throughput of 802.15.4Standard

The result shows that the power consumption of EEMAC is optimized, and it is lower than the power consumption of MAC802.15.4 and the power consumption of ABE. The power consumption of EEMAC is lower than the power consumption of ABE by 40%. The reason is that the datagram sent by the nodes of ABE would be increased at high transfer rate, and this situation makes the datagram conflict continuously. So the power consumption of ABE would be increased accordingly. The power consumption of EEMAC is lower than the power consumption of 802.15.4 by 32%. The reason is that the algorithm of EEMAC is the adaptive backoff index algorithm, and it could make the power consumption stay on a stable level. From the above discussion, the adaptive backoff index algorithm of EEMAC has a positive effect on reducing the power consumption.

3. Conclusions

(a).The power consumption of PSK is the lowest in the design and the realized of the wireless sensor network node. The power consumption of communicating module could be lower by increasing sleeping time or wireless communication method of multihopping short-range.

(b).The algorithm of EEMAC consumes the least power in the MAC of wireless sensor network node.

(c).The results show that the algorithm of EEMAC and the modulation of PSK are very compatible with the cooperations of many nodes.

These results are very helpful to the structure optimization of the wireless sensor network node of ZigBee and the reducing of the power consumption of transfer data.

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